OPERATING INSTRUCTIONS

FOR

BAIRD – ATOMIC, INC.

DENSITOMETER – COMPARATOR

MODEL CB

INSTRUMENT
CENTER

Baird-Atomic, Inc.

University Rd., Cambridge 38, Mass.

OPERATING INSTRUCTIONS
BAIRD-ATOMIC, INC.
DENSITOMETER - COMPARATOR
MODEL CB

—

27 February 1961

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Chapter I

GENERAL INFORMATION

A. General Description

The Baird-Atomic, Inc., Densitometer-Comparator, Model CB, is designed primarily for measuring peak spectrum line densities in photographic spectra. The instrument finds its most extensive application in the field of quantitative spectrochemical analysis, although the instrument will be found useful in any field requiring the precise determination of density.

The B/A Double-Beam Densitometer-Comparator utilizes the two-beam optical null method with a servo-type automatic balancing system. The unit reads directly on a linear scale with high accuracy. Provision is also made for the attachment of a standard recorder when needed. The Densitometer-Comparator is designed for convenient measuring of line spectra densities on photographic plates or films. Other applications include photography, x-ray analysis, and calibration of neutral filters.

The Densitometer-Comparator design was developed for speed and convenience of operation. The sample spectrum plate is placed on a movable plateholder at the front of the main carriage with the standard master plate in the rear. Viewing screen, density scale, and operating range meter are all at convenient eye level. The illuminated density scale is viewed through an enlarging lens with a circular polarizer to eliminate light reflections.

Each plate rests on its own plateholder with separate rack and pinion adjustments for vertical translation. Any spectrum on one plate can be compared with any spectrum on the other. Standard plateholders will take 4" x 10" and 4" x 14" plates. The motor-driven plate-scanning mechanism also contains a manual override. Power scanning with two standard speeds of 8 and 35 microns per second is provided (other speeds can be specified). With either manual or motor scanning, from 3 to 6 lines per minute can be measured.

B. Double-Beam Optical System

The optical system of the Baird-Atomic Densitometer-Comparator consists of two light sources. One of these sources is for the sample and measuring beam (B1); the second source is for the comparison plate beam (B2). Figure 1 shows the complete optical system in diagrammatic form. The light sources B1 and B2 are located in the base of the instrument with projection lenses P1 and P2 in the overhanging arm. There is simultaneous projection of the sample and comparison plates on the screen at a 10X magnification.

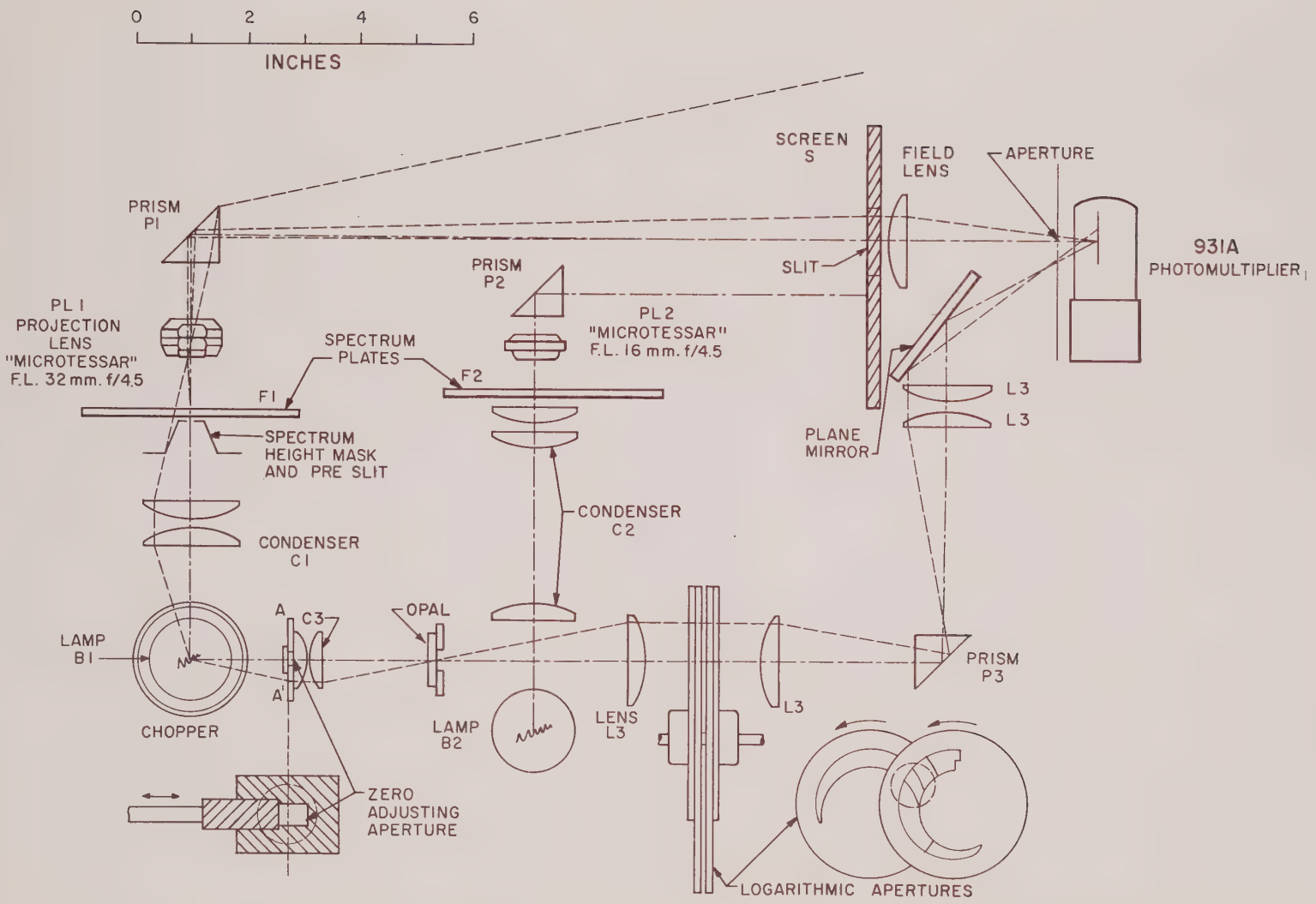


FIGURE 1 – OPTICAL SCHEMATIC

A fixed 12 mm x 0.100 mm slit in the center of the sample spectrum field transmits light to the photomultiplier tube. The aperture in front of the photocell acts to exclude all light except that which is transmitted by the projector, thus making the instrument unaffected by room, stray, and scattered light.

The reference beam is derived from the same source as the measuring beam. It passes through adjustable apertures to the photomultiplier. The precision logarithmic aperture is in the form of tapered annular openings on two rotating discs. The logarithm of the aperture is proportional to the angle of shaft rotation. The aperture is varied by the action of the servo motor until the transmissions of the aperture and sample plate are equal. The shaft angle is mechanically transmitted to the density scale which displays the density of the sample plate.

A zero-adjustment aperture is provided to facilitate the selection of any convenient point as zero density. For example, the particular application may call for the selection of clear glass, clear emulsion, or the background between lines as the point of zero density. A zero control knob is provided for this purpose. Only the zero end of the scale is set in this type of instrument.

C. Self-Balancing Null-Indicator Type Electronic System

The Baird-Atomic Densitometer-Comparator electronic system operates on the principle of a self-balancing null indicator arrangement. The electronic system is shown below in circuit form in Figure 2.

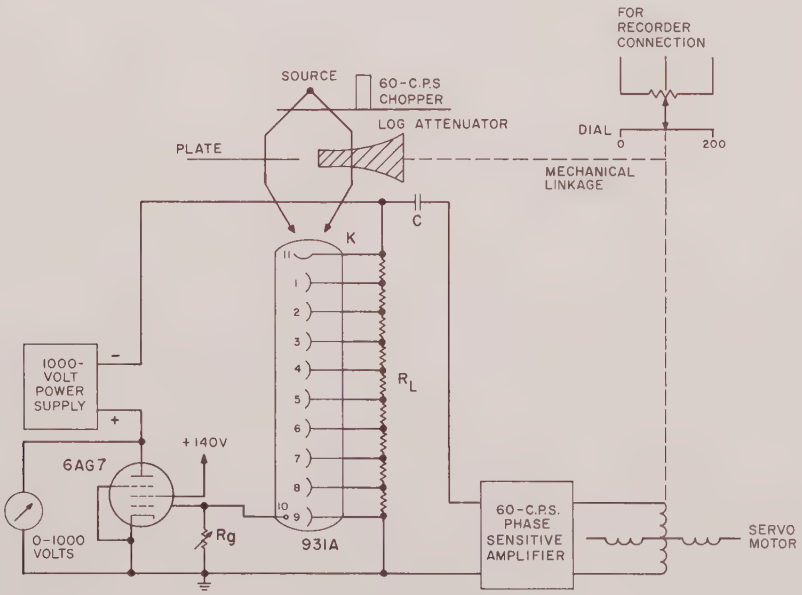


FIGURE 2 - SERVO ELECTRONIC SYSTEM SCHEMATIC

The servo balancing system automatically adjusts the intensity of the reference beam to that of the measuring beam. A 60-cycle chopper alternates the beams through their optical systems to the photomultiplier. Unequal intensities in the two beams results in a 60-cycle error signal that is amplified and supplied to the servo motor which drives the logarithmic aperture shafts. The density scale is geared to the servo motor.

Other features of the electronic system include an antilogarithmic function from the electrical gain. In this way the servo system has the same operating characteristics over the entire density range from 0 to 2.0. Response time is approximately 3 seconds for full-scale readings. Reproducibility is within ± 0.003 density unit. There is no observable drift, even over long periods of time.

D. Specifications*

Viewing Screen	4" x 5"
Spectrum Projected	0.5"
Magnification	10X
Dimension of Slit (effective at plate)	1.2 mm x 10 microns standard (others can be supplied)
Detector	931A photomultiplier
Dial	0 to 2.0 density units in 200 linear divisions (spread around 270 degrees of the circumference of a circular scale 4" in diameter, magnified, illuminated and shielded from room illumination)
	Optional: transmission, 1% to 100%, in two logarithmic cycles
Sensitivity	Sufficient to obtain 0.003 density unit stability, and reproducibility at density 2.0 with scanned area 2000 sq. microns or greater
Response Time	3 seconds for full-scale deflection, recording or nonrecording
Stability	No drift or transient response greater than 0.003 density unit at any density reading
Reproducibility	± 0.003 density unit

*We reserve the right to depart from catalog specifications.

Linearity	Departure less than ± 0.01 density unit for any differential reading
Speed	3 to 6 lines/minute easily read without operator strain
Scattered Light	H. & D. curve deviation from a straight line at density 1.70 less than 0.10 density unit (tentative A. S. T. M. specification)
Scanning	Manual at 2000 microns per revolution of knob; or automatic at 2 speeds, 8 or 35 microns/second
Recorder	Strip chart recorder optional. Pen speed, 2 seconds full scale, chart speed 2"/minute
Vibration Mounts	None required
Voltage Regulation	None required for lines fluctuating no more than 100 to 125 volts
Power Required	200 watts, 115 volts AC
Space Required	28" deep x 22" wide x 16" high
Weight	140 lb
Shipping Weight	160 lb

E. Laboratory Space Required

The Densitometer-Comparator is compactly designed into an instrument measuring about 22" x 28" x 16" high. A clean laboratory table surface 50" x 36" of standard desk or table height is adequate. The controls have been positioned for maximum convenience and speed for reading spectrochemical plates routinely without recording. The right hand is left free for writing the data. A desk leaf at the right is a convenience for holding the record sheet, although this may be placed at the right of the instrument.

When a strip chart recorder is used with the instrument, it may be placed either on the table adjacent to the Densitometer or it may be mounted on a 7-foot portable relay rack placed beside the table. Another possibility, which is more conservative of space, is to build a shelf above the hood of the Densitometer for holding the recorder.

F. Power Required

The instrument is operated on 115 volts, 60 cycles; the current drawn is two amperes. No voltage regulator is required due to the fact that, with the double-beam measuring system with single source and detector, any change in lamp brightness or detector sensitivity affects both beams equally. The final density is thus rendered independent of line voltage fluctuations from approximately 100 to 125

volts. Voltages beyond this range cause trouble, because the filaments of the electron tubes and the lamp sources are incorrectly operated. Normal operation should be from a 115-volt supply, ± 5 volts.

Chapter II

SHIPMENT AND UNPACKING

A. Shipment

The Densitometer is packed in a single crate for shipment. The instrument is double-wrapped in protective water-proofed paper; excelsior completely surrounds the wrapped instrument.

B. Unpacking

Two men can easily lift the wrapped Densitometer from the crate. After unwrapping, two wooden braces which prevent the stages from moving while in shipment can be easily removed, as can the tape supporting the stages and the prisms. No internal parts are secured for shipment.

C. Reporting of Damage

Any damage obvious at the time of unpacking should be reported at once to the common carrier with a request for examination by an inspector. Responsibility for filing claim for damage rests on the consignee whenever the instrument is shipped f. o. b., our plant, which is the usual mode of shipment.

Chapter III

DESCRIPTION AND LOCATION OF CONTROLS

The controls on the outside of the instrument are called out in Figures 3 and 4, and are discussed in paragraphs A through J, following.

A. Power Switch (1)

The Power switch is a heavy-duty three-way switch, and is the middle of the three switches located on the left side of the instrument. The upper position is ON; the two lower positions are OFF. No pilot lamp to indicate ON is provided, since the two lamps projecting spectra on the screen (15) and the indicating dial (16) illumination lamp all serve this purpose.

B. Balancing Motor Phase Switch (2)

The Balancing Motor Phase switch is the rear of the three switches on the left side. Every time the power to the instrument is interrupted and reconnected, there are two positions in which the poles of the chopper motor may lock synchronously with the field excitation of the servo balancing motor. The choice between these phases is random each time the instrument is energized. If they are in-phase, the servo drives toward balance. If they are out-of-phase, the servo drives away from balance. The direction of servo drive can easily be tested by blocking the sample beam with the hand. The Balancing Motor Phase switch is provided for reversing the phase when locking out-of-phase occurs. Operating this switch from one extreme to the other instantly corrects the phase of balancing. The central position is OFF, and in this position all power is removed from the balancing motor. This is very occasionally useful during testing of the instrument, as the log aperture may then be manually set to any position. Once the proper phase is found, it will never change until the instrument power switch is turned off.

C. Fuse (3)

The fuse is a buss, AGC 3 amperes, 250 volts.

D. Recorder Connection (4)

The recorder connection is a three-wire Amphenol connector, AN3102A-14S-7S.

E. Zero Control (5)

The zero control is the only control on the right-hand side of the instrument. Its function is to adjust an aperture in the measuring

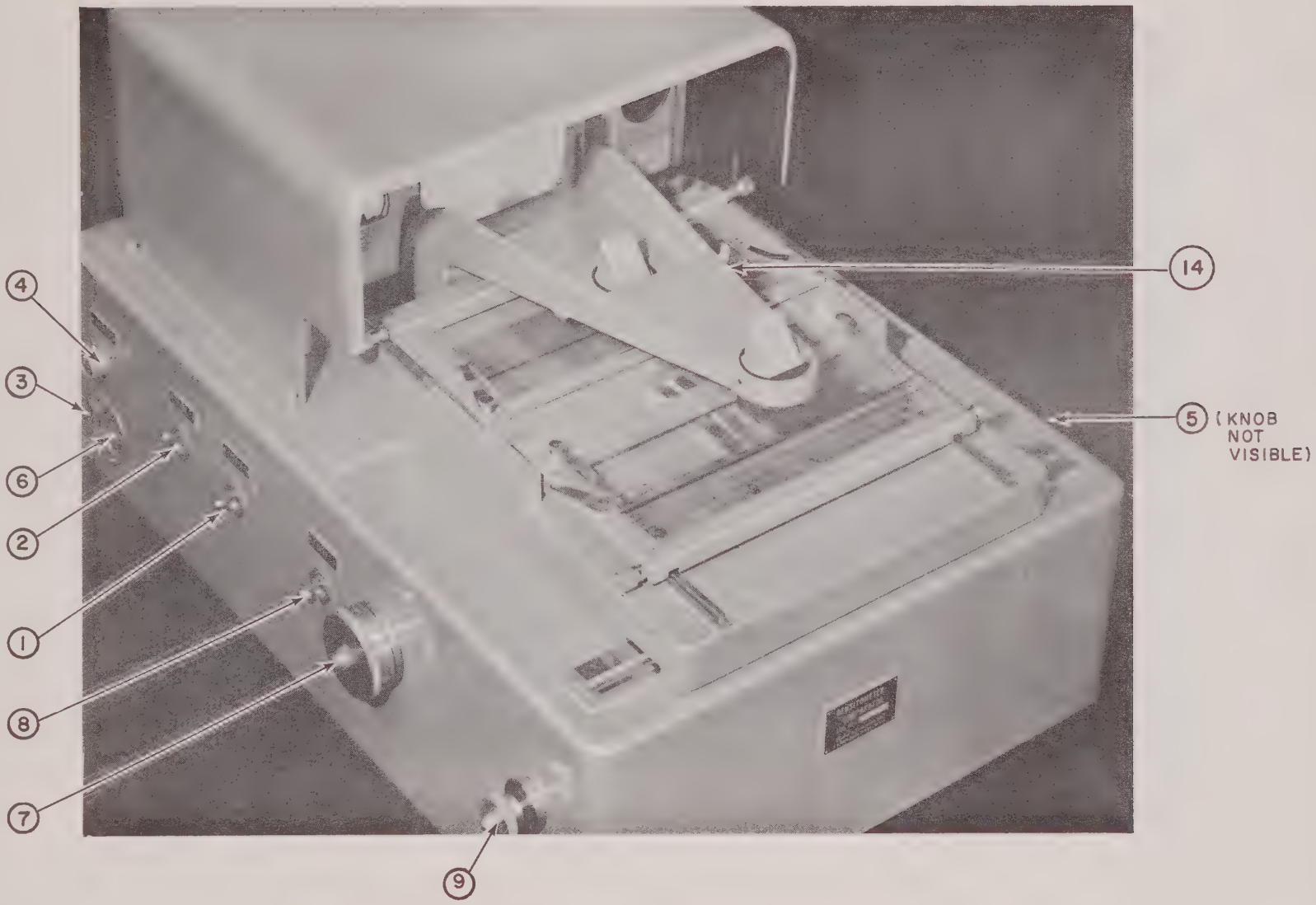


FIG. 3 DENSITOMETER - SIDE CONTROLS

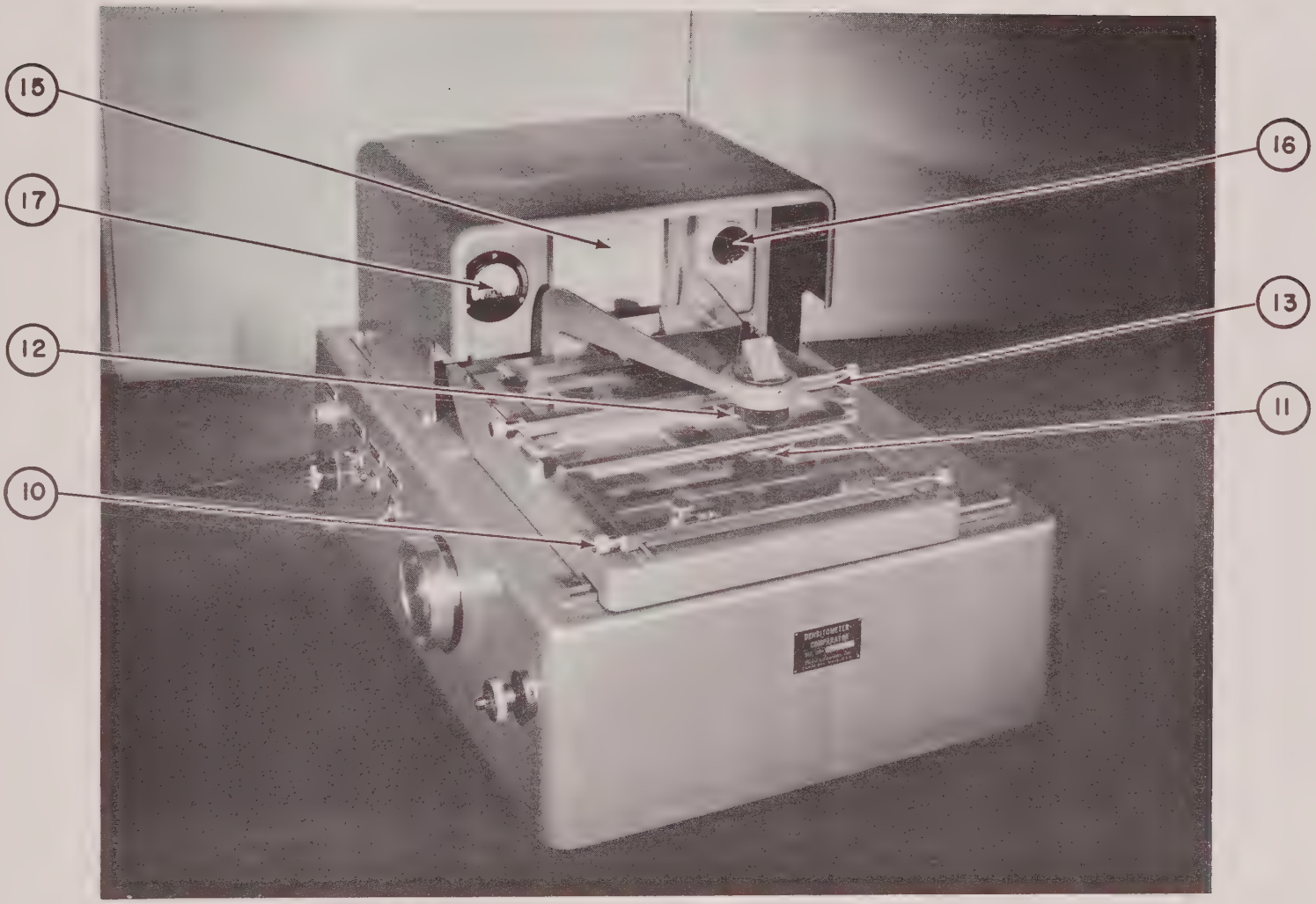


FIG. 4 DENSITOMETER - TOP CONTROLS

light path which permits arbitrary setting of the point that is to be considered as reference zero density. The most common choice for zero density is a clear region of unexposed plate or film. Other choices are: clear glass with emulsion removed, air, or optical background. It should be remembered that the difference of two densities is independent of the zero setting. For those who have been accustomed to transmission scales, it is the ratio of two transmissions which is independent of the zero setting.

F. Power Input Receptacle (6)

The power input receptacle receives the 115-volt line plug. It is an Amphenol, type 61-M10.

G. Manual Carriage Scan (7)

The manual scan wheel is designed for most convenient operation, with the thumb of the left hand. For manual reading, the image of the edge of the spectrum line is brought rapidly to the edge of the entrance slit. Then the thumb moves the control very slowly and evenly so that the line is scanned at a rate which permits reading of the peak density without error.

H. Motor Scan Switch (8)

A motor-driven scan is also provided. The switch has three positions: forward, reverse, and off in the center position.

I. Motor Scan Gear Shift Lever (9)

Provision is made for two speeds of motor scanning which are changed by the gear shift knob, located forward on the left side of the instrument. These speeds are 35 and 8 microns/second. The slow speed is used for the measurement of most line spectra. The fast speed is used for line spectra taken with very wide slits, or for other types of density measurements which permit more rapid scanning. The gear shift lever changes the gears when the shaft is pulled in or out. Keeping the Motor Scan switch on helps the gear teeth to mesh in place. The "out" position of the knob is the slow-speed position.

More convenient than manual scanning is automatic scanning. The motor and manual scans are connected to the carriage through a differential so that they can be used either independently or simultaneously. The line image is rapidly brought to the edge of the slit by means of the manual wheel, and then the motor scans the line image slowly past the entrace slit. In using this method, care must be taken to approach the slit manually in the same direction in which the motor is scanning.

For rapid translation of the carriage from one line to another some inches away, the carriage itself is easily pushed into position, using both hands. A friction clutch prevents injury to the parts of either the manual or motor scan. It does not matter if the motor scan is running.

J. Vertical Translation of Plate (10)

A fixed rack and movable pinion is used to select one from many spectra on a single plate and to locate accurately the height of the entrance slit between the ends of the image of the spectrum line.

Chapter IV

IMPORTANT COMPONENTS

A. Pre-Slit

Just beneath the emulsion, there is mounted on the optical axis a pre-slit formed by jaws made from a yellow filter glass (11). This pre-slit has been carefully positioned at the factory so that it will have its top surface 0.003 to 0.004 inch beneath the emulsion. Its position should, however, be checked at the time of installation. A feeler gauge inserted between the top of the pre-slit and the bottom of a plate firmly held in the plate-holder may be used for testing this distance. Care should be taken not to bend the plate during this test. The pre-slit may be adjusted for correct distance by releasing the Allen screws left and right, and by pulling up or pushing down the pre-slit as required. A final check must always be made after tightening the Allen screws.

The cover glass on top of the pre-slit is extremely thin (0.003 inch), and care should always be exercised to prevent the plate or other object from impinging on the surface of the cover glass.

The pre-slit serves the purpose of minimizing the effect of off-axis scattered light in the instrument. Its improper positioning will be demonstrated by the contour of the emulsion characteristic curve,discussed in Chapter VIII.

During focusing, slight movements of the pre-slit image will occur, and it is then necessary to center the pre-slit image on the entrance slit of the Densitometer. The lever (14) is provided to effect slight rotations of the front right-angle prism in order to bring the pre-slit image directly onto the entrance slit. Zeroing of the instrument should be done after the pre-slit image is set, the plate having been previously brought into sharp, critical focus.

B. Comparator Plate Mount

The mount for the comparator plate (13) is just above that of the sample plate. It has the same type of rack and pinion adjustment for vertical translation, which enables corresponding spectra on the two plates to be selected. The horizontal translation of the comparator plate is rigidly coupled to that of the sample plate, since both plates are mounted on the same carriage. Initial horozontal alignment of spectra is accomplished by translating the comparator plate on its holder by the fingers. The purpose of the comparator plate is for rapid identification and location of the lines to be measured on the sample plate. A master spectrum should therefore be prepared with the lines of interest clearly marked. Thus, when many routine

spectra of the same type are to be measured, it is not necessary to find and mark the lines on each individual spectrum. A master plate used on the Comparator can also serve to facilitate rapid qualitative analysis.

C. Focusing of Comparator

Focusing of the Comparator is accomplished by rotating the lens barrel (12) of the projection lens just above the comparator plate mount. With the comparator plate, of course, focus is not such a critical matter as with the sample plate. Slight adjustments of this lens may be utilized to bring lines of master and sample plate into more nearly perfect juxtaposition, the depth of focus being sufficiently large to permit some adjustment of this type.

D. Sample Plateholder

1. This is the forward plateholder on which the plate to be densitometered is placed with the emulsion side down. First turn the thumb screw at the left completely counterclockwise, then pull back the spring lever on the right and rest the plate on the holder, the upper edge being placed against the pivot pin at the top center of the holder. The spring lever is then released so that the plate will be held snugly against the pin. The plate should be pushed down so that it rests on all edges of the plateholder. Rotation of the thumbscrew provides for plate rotation in order to align the spectrum lines with the entrance slit of the Densitometer. For proper measurement of a spectrum line, it is essential that the line image be parallel to the entrance slit.

2. On more recent instruments, the plate is held flat by four spring clips located at each corner of the plate holder. The plate is rotated by hand about the pivot pin at the rear of the holder until the projection of the entire 10-inch spectrum retains the same vertical position on the screen while scanning the length of the plate.

E. Focusing of the Sample Plate

Critical focusing is necessary for accurate spectrum densitometry, especially if the lines are sharp. For large areas of uniform density, however, it is not so important. Accurate focusing is provided by adjustment of the lens barrel (12) holding the Microtessar projection lens. This lens carries an iris diaphragm which must be fully open (F/4.5). If a line is used for focusing, a very sharp line of medium density should be used. Since few lines have entirely sharp edges, some operators find it more critical to make a tiny scratch with a needle in the emulsion and to focus on that. If a dust particle or other defect present in the plate is used for focusing, care must be taken not to use such a defect unless it lies exactly in the plane of the emulsion.

The Densitometer has been designed to measure plates positioned with the emulsion side down. A plate put onto the plateholder should be focused carefully. If the emulsion is down (away from the lens), the focus shifts by (n-1) times the thickness variation, in which expression n is the index of refraction. This is about half the amount of shift that would be realized were the emulsion to be used in the up position. Because of the controlled flatness of the plateholder, subsequent plates should be in focus. Daily checks on focus should be made, however.

F. Film Adapter

The Densitometer may also be used for measurements of spectra recorded on 35-mm film. The film adapter is made in two distinct sections. One of these looks similar to the plateholder, and the plateholder is simply lifted off the tracks and its counterpart is substituted. There is also supplied a small film guide which fits on the pre-slit assembly. Screws supplied with the film-guide assembly fit in obvious positions to secure the film guide to the pre-slit assembly. The purpose of the film guide is to keep the film in a definite plane above the pre-slit.

G. Mounting 35-mm Film

The film should first be inserted emulsion down in the film guide. The ends of the film are then slid through the clamps on both sides of the film cassette. One side is then tightened down with the thumbscrew provided, the film is pulled somewhat taut on the other side and, while holding the film taut, the other clamp is tightened. Alignment of the image of the spectra with the entrance slit is accomplished by turning the thumbscrew on the side of the film holder.

H. Servo System

1. Servo Amplifier

The servo amplifier is mounted by four screws to the rear of the base of the instrument. There are two controls on this amplifier which will be described in the following sections. Since these controls normally do not require adjustment over months of routine operation, it was thought desirable to leave them in a concealed location to prevent inadvertant manipulations.

2. Range Control Potentiometer

The range control potentiometer is the one-megohm potentiometer indicated by R_g in Figure 5. This control corrects for variations in lamp intensity and photomultiplier sensitivity, and restores the operation of the 1P21 photomultiplier tube and the 6AG7

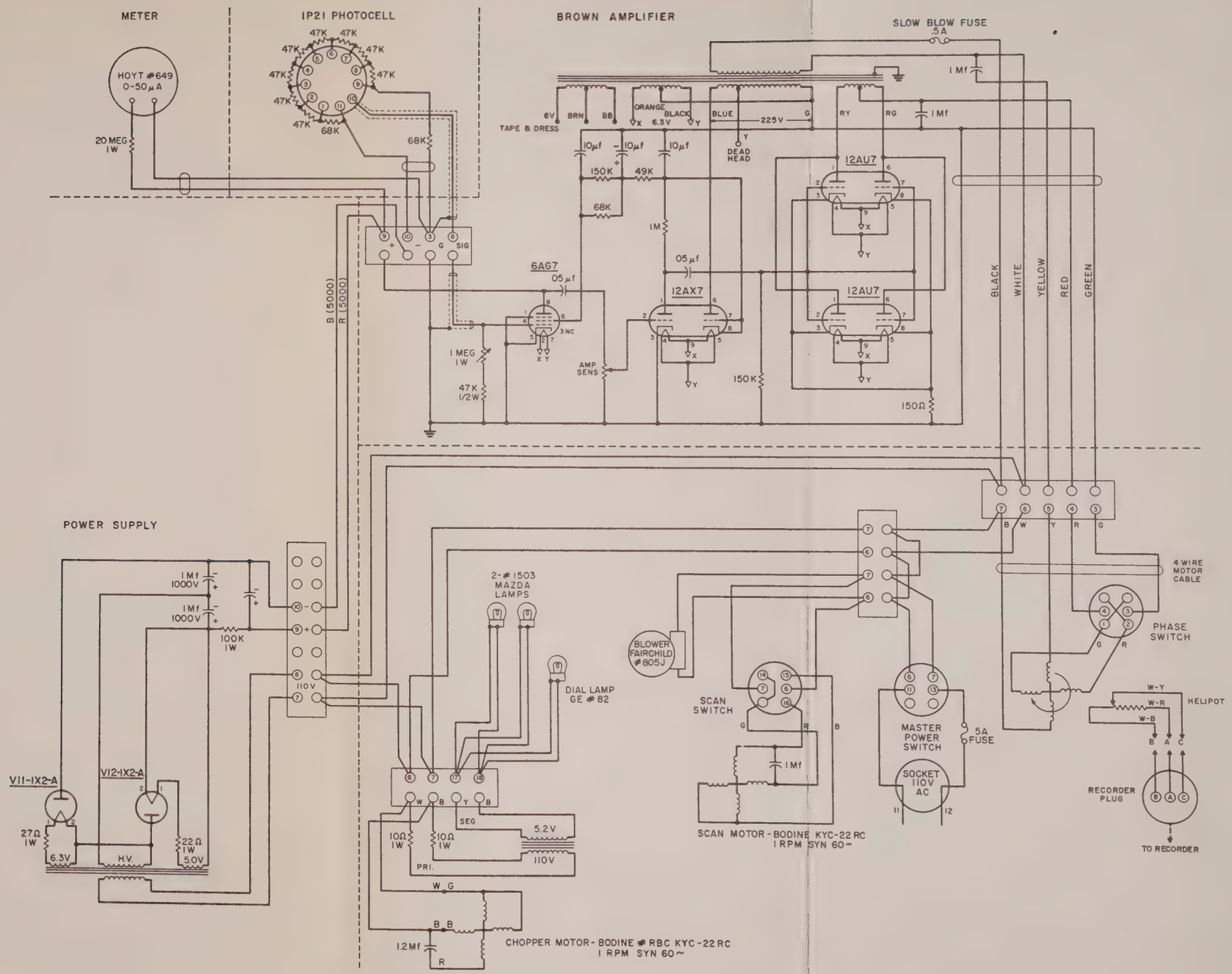


FIG. 5 DENSITOMETER SCHEMATIC DIAGRAM

control tube to the optimum region of their characteristics. The procedure is to balance the instrument at zero density (100 per cent transmission) and then to adjust the potentiometer (R_g) until the 0 to 1000-volt operating range meter (17) reads between 5 and 7 on the scale (500 to 700 volts). The potentiometer has been adjusted at the factory so that the operating range meter reads 5-7 when the line voltage is 115 volts. This meter reading will vary correspondingly to the line voltage, decreasing about 100 volts for a 5-volt drop in line voltage. As a dense spectrum line is scanned, the operating range meter drops linearly to about 75 volts or lower at a density of 2.0. If it is not possible to reach as high as 500 volts at density zero with the potentiometer control, it is an indication that:

(1) the light may be weak, requiring the insertion of a new lamp,

(2) the phototube needs changing,

(3) the alignment of the optics of the upper beam should be checked, or

(4) the line voltage is low.

Conversely, if the meter reading cannot be brought down to 700 volts at density zero, it indicates that:

(1) there is too much light,

(2) a less sensitive photocell must be used, or

(3) that the line voltage is unusually high.

The important thing in the adjustment of this control is that the servo motor show no tendency to sluggishness at a density of 2.0. Set the instrument on a very dark line of density about 1.95. Intercept the beam with the hand and note whether or not the scale moves without sluggishness to 2.0 and then back when the hand is removed. If this is not the case, then R_g must be advanced. The clear plate reading at density zero of the range meter is unimportant as long as the above criterion is met.

3. Servo Gain Control

The gain of the voltage amplifier in the servo loop is controlled from a recessed potentiometer in the middle of the servo amplifier chassis. On some instruments, the gain control is under a cap on the extreme left front of the top of the amplifier. This controls the ratio of the motor torque to the off-balance flicker signal, and thus determines the "liveness" of the servo balancing. If this gain is too high, the density dial will "overshoot" slightly when returning to a reading. This can be tested by momentarily interrupting the sample beam with the hand. If the servo gain is too low, there

may be a "dead spot"; i.e., a region of uncertainty in which the servo motor does not have sufficient torque to find balance, or the motor balance may otherwise show deadness, slow response, or other indication of weak driving signal.

When the proper servo amplifier gain setting is found, there should be no dead spot greater than 1/3 of one division (one division is 0.01 density unit). The overshoot may be as large as three small divisions (0.03 density unit), but the important criterion is the rapidity of return to the zero setting. Many operators already familiar with the operation of galvanometer-type densitometers may tend toward an adjustment which is actually indicative of an insufficiently "live" servo. A "live" servo may tend to give the density dial a slightly jerky behavior as a spectrum line is being scanned. However, this in no way affects the accuracy of reading the peak density and, in fact, it is only with a "live" servo that accurate, reproducible measurements can be made.

Once the servo gain control is set, the gain should be independent of lamp brightness or phototube sensitivity due to the action of the 6AG7 circuit, providing it is properly adjusted as in paragraph b. A slight adjustment of the servo amplifier gain may be necessary if the phototube is replaced by a new one. Although the 6AG7 control circuit regulates against variations in phototube sensitivity to light variations, a different over-all servo gain may result if the new phototube demonstrates a different slope of gain versus dynode voltage.

I. Screen and Slit

The screen material is white celluloid, matte finished, 0.030 inch thick.

The standard slit size is 0.004 inch (100 microns) by 0.480 inch (12 millimeters) at the screen. Since the projector magnifies the plate 10 times, the effective slit dimension at the plate is 10 microns by 1.2 millimeters. (Other slit dimensions can be supplied if desired.) The screen is easily removable, so that a variety of slits can be used if it should be necessary. Inasmuch as a field lens focuses an image of the projector lens on a pinhole in front of the photomultiplier, it is not necessary to make any other changes in the sample beam optics when changing slits. This field lens also prevents room light from entering the photocell.

The light intensity transmitted through the screen to the photomultiplier is directly proportional to the area of the slit. Therefore, it is necessary to adjust the zero control if the slit is changed. If large changes in slit area are introduced, it may even

be necessary to introduce neutral filtering in the lower beam in order to match intensities within the range of variation of the zero control.

J. Density Indicator Dial

The density is read on the dial on the right side of the instrument. This dial is coupled by a nylon suture cord to the rotation of the precision logarithmic light attenuator. This dial is illuminated by a small lamp and is viewed through a magnifying lens. A circular polarizer is employed to reduce glare from lights reflected from the room.

A dial reading directly in per cent transmission can be supplied for users possessing calculating equipment calibrated in transmission units.

Chapter V

ROUTINE OPERATION

A suggested order of procedure in routine operation is as follows:

1. Turn power switch on (Chapter III, paragraph A).
2. Allow instrument to warm up for at least five minutes.
3. Insert plate or film (Chapter IV, paragraphs D and G).
4. Test focus (Chapter IV, paragraph E).
5. Align spectrum lines with entrance slit (Chapter IV, paragraph D).
6. Align image of pre-slit (Chapter IV, last paragraph under A).
7. Set zero of instrument on clear portion (fog level) of the plate (Chapter III, paragraph E). Inasmuch as the fog level may not be constant over the entire plate, many spectrographers adopt a standard procedure for setting the zero. Many set it above each line being measured; others make the setting on an unexposed short section in each spectrum which is the result of a narrow mask inserted in the camera in the spectrograph.
8. Locate and read lines (Chapter III, paragraphs I and J). The automatic scanning method described in paragraph I is recommended. A master comparison plate is helpful for locating lines rapidly. In routine spectrochemical analysis, a plate will generally contain a large number of spectra, each being representative of a sample being analyzed. Usually the same dozen or so lines must be measured in each spectrum. A convenient order is to read the first line on the top spectrum, then the same line on the second spectrum, then successively the same line on all spectra, using the vertical translation pinion described in paragraph J. The vertical translation is then returned to the first spectrum, and the carriage is translated horizontally to the second line of interest, continuing in this way until the plate is completed.
9. Check the reading if desired. The reading on any line may be quickly checked by spinning the handwheel backwards with the middle finger placed on the groove of the wheel until the line has been brought back an appreciable distance on the original side of the slit. Then the handwheel is again reversed until the backlash has been taken up and the line again brought into the measuring position.
10. The operator may secure nonreproducible readings should he be smoking and permitting smoke to pass across the measuring beam.

Chapter VI

THE RECORDING DENSITOMETER

A. Conversion to a Recording Instrument

Recording increases the flexibility of the instrument, permitting the determination of integrated densities, line contour studies, and precise linear measurement. The Densitometer has been made ready for simple conversion to a recording instrument; all that is required is the coupling of a heavy-duty, three-turn helipot to the rotation of the precision measuring aperture. A three-wire Amphenol connector is provided on the side of the instruments for connection to any of a number of standard commercial makes of strip chart recorder. This electrical connection is only to the helipot; there is no electrical connection between any part of the recorder and the Densitometer electronics. The helipot is not supplied when the Densitometer is purchased as a nonrecording instrument, but it is supplied on order and may be easily installed by the user. This helipot is connected into any recorder in either an AC or a DC Wheatstone Bridge input circuit. The Bristol recorder normally supplied with the instrument utilizes an AC follower circuit.

A DC follower circuit suitable for connecting to a Brown Elecktronic recorder is shown in Figure 6, and the circuit supplied by the Bristol Company in Figure 7. Baird-Atomic can furnish recorders (of several makes) with the proper input circuit already arranged, or the customer may use a recorder already available. It is recommended that the recorder have about a two-second pen response time, and a chart speed of approximately two inches per second.

B. Matching of Recorder and Densitometer Readings

The potentiometers labeled "zero" and "span" are used to match the recorder reading scale to that of the Densitometer. In the Bristol recorder these capped controls are located beneath the lower protective plate on the back side of the chart drive and slide-wire assembly. By adjusting the zero, the recorder can be brought into agreement with the zero of the Densitometer. With the Phasing switch off, the Densitometer should then be set on a spectrum line of a density very near to 2.0. This can be done by manually rotating the aperture gears until the desired reading is reached. The span is then adjusted until the recorder reading agrees with the Densitometer reading. It is then necessary to check the agreement at density zero, making any necessary adjustment to zero. Inasmuch as an adjustment to either zero or span can affect the one not adjusted, it is necessary to check both ends of the scale after each adjustment. After three or four trials, positions for zero and span will be found for agreement of the recorder with the Densitometer at both ends of the range.

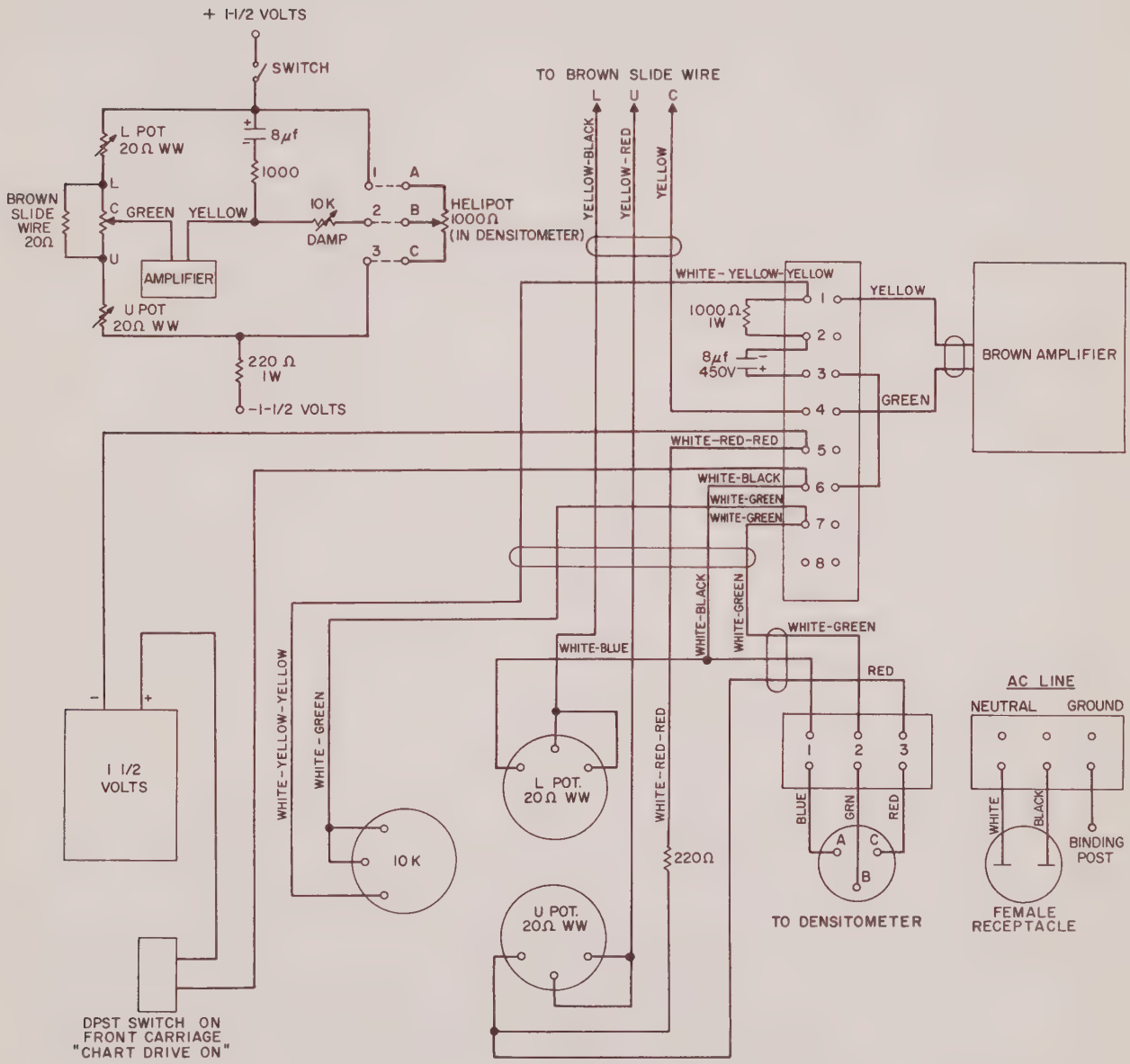


FIGURE 6. DIAGRAM, WIRING BROWN RECORDER REWORK

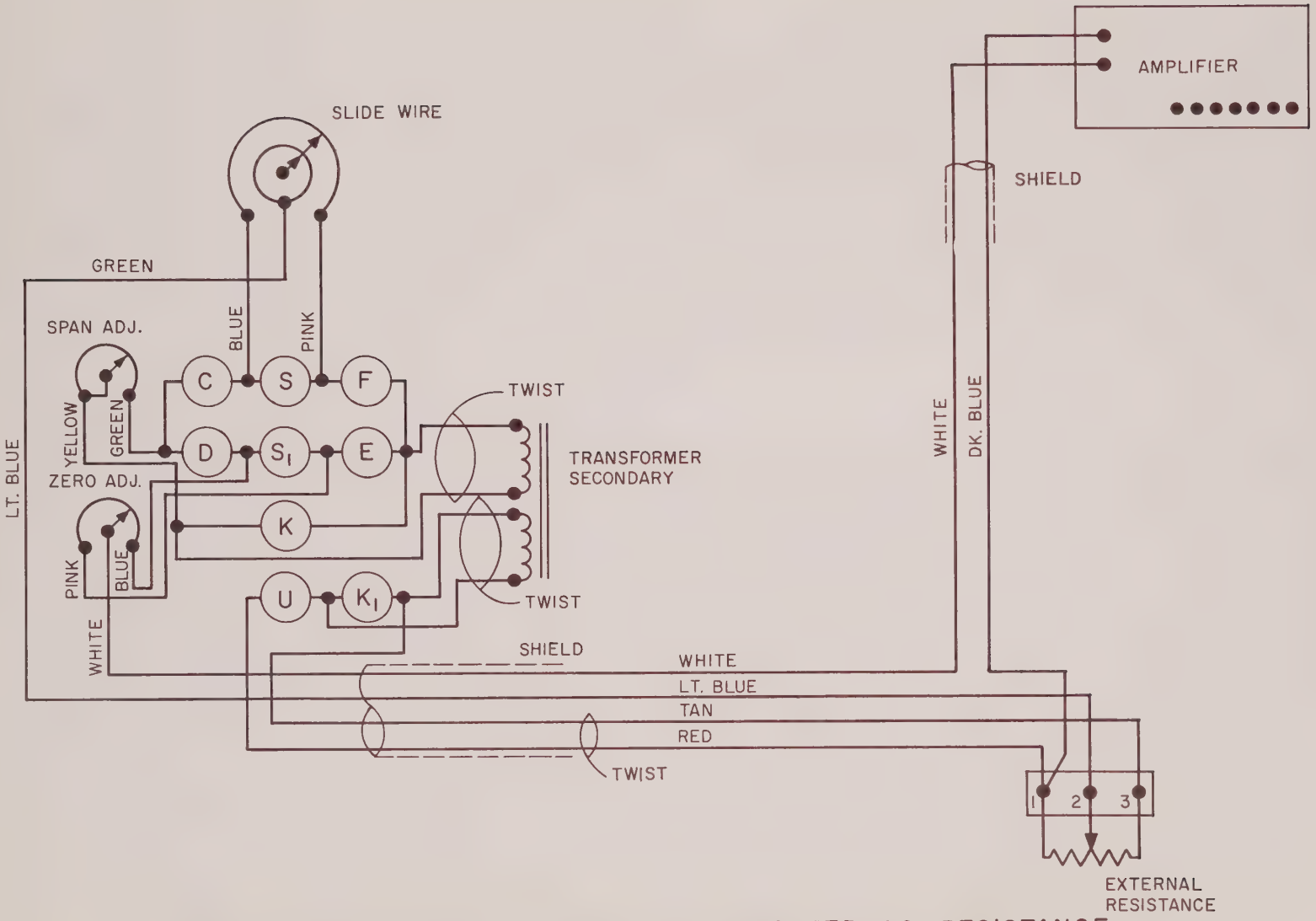


FIGURE 7 — MEASURING CIRCUIT DYNAMASTER AC RESISTANCE RECORDER WITH SPAN AND ZERO ADJUSTMENTS

The other potentiometer requiring adjustment is used to control the damping of the recorder, and this should be adjusted to the point at which the recorder shows a definite "liveness" in its action. If the recorder shows no "noise level" at all, it is over-damped and inaccurate readings will result. This control is located on the left front of the top of the amplifier chassis.

Chapter VII

TROUBLESHOOTING

A. Lamp Changing

1. General

The lamps, G. E. Mazda type 1503 (single-filament auto-motive-type headlamp bulbs), have a rating of approximately 1000 hours life at the normal operating voltage of 5.2 volts rms. The voltage from a 6.3-volt transformer is dropped to this value by resistors in series with the primary; therefore, one may expect to have to change lamps at intervals of approximately six weeks under 24-hour continuous operation, with correspondingly longer periods under a shorter duty period.

It is not desirable to wait for actual burnout before lamp changing, as the evaporation of tungsten will cause a blackening of the glass envelope and some loss in illumination. Compensation for a darkening lamp can be made to some degree by adjustment of the range control potentiometer (see Chapter IV, paragraph H, b).

2. Procedure

Turn the instrument on its right side in order to change lamps.

CAUTION

When setting the instrument on its side, support the carriage so that it will not strike the lens barrels. The sensitivity control knob on the right side must also be protected. Some wooden blocks on which some sponge rubber has been mounted serve nicely to support the instrument with the right side slightly elevated so that the sensitivity control knob has no weight on it.

First remove the plateholders. Removal of the bottom plate reveals the rectangular plate to which the lamp socket is mounted. This plate in turn is held by three screws (No. 8 Allen head) to the source mounting bracket. The proper way to change the lamp is to remove these three screws and the rectangular plate. Then the lamp can be removed from the socket and the new lamp inserted. NOTE: SINCE THE EXACT POSITION OF THE LAMP RELATIVE TO THE CHOPPER BLADE IS VERY CRITICAL, IT IS IMPORTANT THAT NONE OF THE OTHER SCREWS INVOLVED IN THE MOUNTING OF LAMP OR CHOPPER BE DISTURBED. DO NOT REMOVE THE RIGHT ANGLE BRACKET ON WHICH THE LAMP PLATE IS MOUNTED.

When the lamp is changed by the method indicated, the prefocusing base construction insures that the filament will be restored to exactly its original position.

B. Internal Parts

Figure 8 is a photograph of the bottom of the instrument with the dust cover removed, showing the internal parts. The parts called out by letter on this drawing are:

A Sample beam lamp

B Comparison beam lamp

C Source mounting bracket and lamp plate

D Chopper

E Scan motor

F Terminal strip for lamp transformers. 110 volts, 60 cps, appears across terminals 6 and 7. This may be nearer to 100 volts due to dropping resistors. 5.2 volts, 60 cps, appears across terminals 17 and 18

G Terminal strip for high voltage supply. 110 volts, 60 cps, appears across terminals 6 and 7. About 1000 volts DC appears across terminals 9 and 10 (neither side is grounded). 9 is plus and 10 is minus

H Precision logarithmic apertures

I Servo balancing motor

J Helipot for recorder connection.

C. Adjustment of Friction Clutch

The friction clutch which permits the operator to override the automatic scan may in time require tightening. The knob for tightening this, labeled (K) in Figure 8, may be reached without removing the bottom dust cover by pulling the instrument slightly over the table top. A round opening has been provided in the dust cover for reaching the knob which tightens the clutch.

D. General

Any defect in the operation of the Densitometer will usually be immediately apparent in abnormal behavior of the operating range meter on the front panel. If this indicates no voltage under any

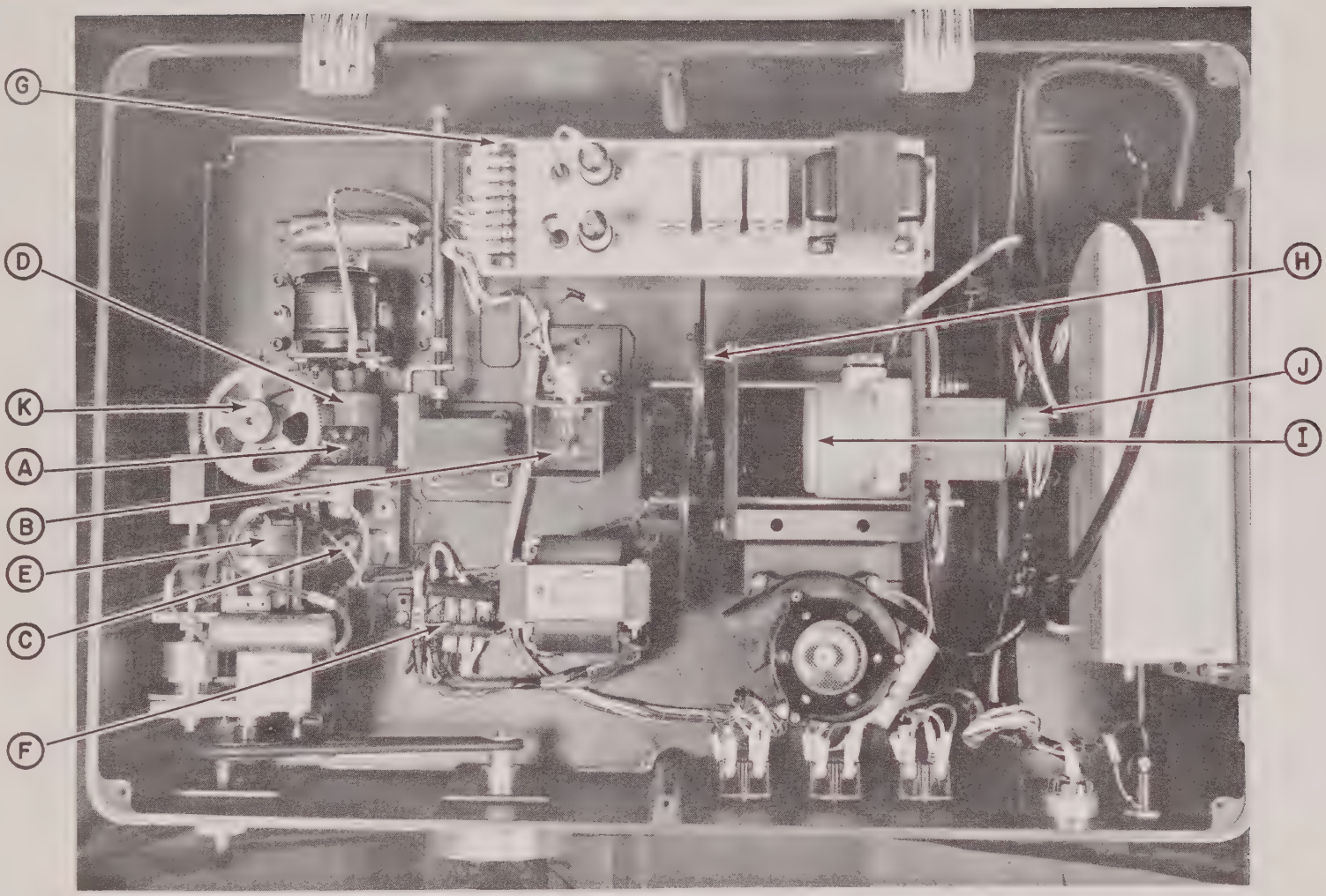


FIG. 8 DENSITOMETER - BOTTOM VIEW

conditions, a check should be made of the output voltage of the high-voltage power supply (terminals 9 and 10). The photocell dynode supply resistors (about 500,000 ohms total) and the 6AG7 tube are connected in series with the high-voltage power supply. Insertion of a new 6AG7 tube will usually indicate whether it is faulty. The 500,000 - ohm photocell resistors can be read and checked from terminal 10 to ground if the power to the instrument is off.

The chopper light signal can be observed between terminal 9 and ground with an oscilloscope. The DC voltage on terminal 9 is indicated by the operating range meter. Care should be taken not to exceed the voltage rating of the DC blocking condenser on the input of the oscilloscope. The meter voltage can be reduced by turning the range control potentiometer if necessary. Observation of this light signal as the transmission of the two beams is varied gives a quick analysis of any defects in lamp, chopper, optical alignment, or photocell.

If this light signal appears normal, but the servo cannot be made to operate by adjustment of the gain control or by replacement of the tubes, then the trouble is probably in the servo amplifier.

If these simple observations do not indicate the source of trouble, and the optical and mechanical parts appear normal, it is suggested that the Baird-Atomic Engineering Department be contacted and the trouble described.

E. Recommended Spare Parts

The following list does not include recommended spare parts for the strip chart recorder when such a recorder is used to make the Densitometer a recording instrument. For such parts, the recommendations of the manufacturer should be followed. The following parts for the Densitometer are advised.

Quantity	Description
3	1503 G. E. Mazda, 6-volt, single filament auto headlamp bulbs
1	1P21 RCA electron multiplier phototube of selected sensitivity (selected and tested for the application by Baird-Atomic)
1	6AG7 tube
2	1X2A tubes
1	12AU7 tube
1	12AX7 tube
3	Buss fuse MDL, 1/2-ampere, slow-blow, 250-volt, for servo amplifier chassis
3	Buss fuse, AGC 3-ampere, 250-volt, for main chassis

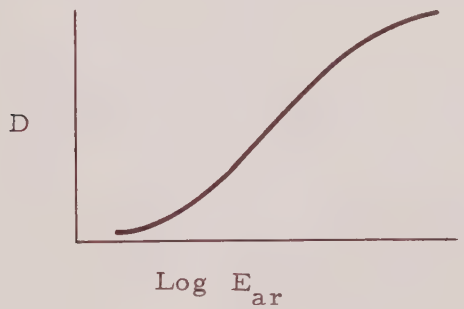
Chapter VIII

NOTES ON USE OF DENSITOMETER IN QUANTITATIVE SPECTROCHEMICAL ANALYSIS

A. Plotting the H. and D. (Hurter and Driffield) Emulsion Characteristic Response Curve

The H. and D. curve is a plot of the density as ordinate against the logarithm of relative exposure as abscissa. It is necessary to procure density measurements on lines or segments of lines caused by radiation of known exposure ratio. For a review of the methods in common use, the following well-written article is suggested: "Suggested Practices for Photographic Photometry in Spectrochemical Analysis," Cyrus Feldman, Methods for Emission Spectrochemical Analysis, American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.

A typical H. and D. plot is shown in the following diagram:



The slope of the straight line portion (tan θ) is dependent upon the emulsion used, the developer used, and the processing conditions. Temperature and time of development are important factors, and consequently these conditions must be precisely controlled. The slope of the straight line portion of the curve is called "gamma". It is important that one H. and D. curve not be used over too broad a wave length range, inasmuch as gamma is also a function of wave length. Normally one curve may be used for SA No. 1 emulsion, and indeed for most present day emulsions, between 2500 and 3100 A. The gamma generally changes rapidly outside of this wave length region.

The use of the H. and D. curve permits the determination of exposure ratios over the entire length of the curve, not restricting the spectrochemist to the straight line portion. Analytical working curves are then prepared by plotting the logarithm of concentration

against the logarithm of the ratio of the relative exposure of the analytical line to that of the internal standard line.

With this method, it is possible to make background corrections. To do this, it is necessary to determine from the H. and D. curve the relative exposure for the spectrum line and the relative exposure for the background; the latter is then subtracted from the former.

B. Density Difference Method

This method is almost completely limited to exposures represented by the straight line portion of the H. and D. curve. The application of the method requires:

(1) Precise control over development conditions;

(2) Selection of lines either on or almost on the straight line portion of the H. and D. curve; and

(3) The exposure of one or more standards on each plate.

The straight line portion of the H. and D. curve may be represented by the following equation:

$$D = \text{gamma} \log E_r + b$$

Then, for the difference in density of two spectrum lines, the following can be written:

$$D_1 - D_2 = \text{gamma} (\log E_{r1} - \log E_{r2}),$$

$$= \text{gamma} (\log E_{r1} / E_{r2})$$

Therefore, the difference in densities of the analytical line and the internal standard line is directly proportional to the log of the ratio of the relative exposures. Analytical working curves are, therefore, constructed by plotting $(D_1 - D_2)$ as abscissa against the logarithm of the concentration as ordinate.

The Baird-Atomic Densitometer, because it reads directly in density units, makes the application of the density difference method both easy and rapid. The method, however, implies either that standards appear on the plate with the samples or that a suitable control line pair be used for correcting for gamma differences. Laboratories that have processing conditions controlled to such a degree that they need calibrate only for each emulsion number may find it possible to dispense with this requirement.

An example of a control pair would be two homologous iron lines in the steel spectrum. These lines should have a density difference equal to the value "a", which in fact they did on the plate on which standards were run for calibration purposes. But in a given spectrum, the following situation might exist.

$$D'_{Fe_1} - D'_{Fe_2} = \text{gamma}' \log E_{rFe_1} / E_{rFe_2} = b \qquad (1)$$

The two control lines do not give the correct density difference, and the change has been caused by a shift in gamma to gamma' . The working curves, using silicon as an example, were plotted using $(D_{Si_1} - D_{Fe_1})$ as the abscissa against the logarithm of the concentration of silicon as the ordinate. On the plate carrying the standards,

$$D_{Si_1} - D_{Fe_1} = \text{gamma} \log E_{rSi_1} / E_{rFe_1} \qquad (2)$$

But the control iron pair now shows that the gamma has shifted, and that density differences are now giving:

$$D_{Si_1} - D'_{Fe_1} = \text{gamma}' \log E_{rSi_1} / E_{rFe_1} \qquad (3)$$

It is necessary to convert these gamma' $\log E_{rSi_1} / E_{rFe_1}$ determinations into gamma $\log E_{rSi_1} / E_{rFe_1}$ values. When this is done, the established working curves may be used.

$$D_{Fe_1} - D_{Fe_2} = \text{gamma} \log E_{rFe_1} / E_{rFe_2} = a \, , \qquad (4)$$

$$D'_{Fe_1} - D'_{Fe_2} = \text{gamma}' \log E_{rFe_1} / E_{rFe_2} = b \, . \qquad (1)$$

Dividing Eq. (4) by Eq. (1):

gamma/ gamma' = a/ b ,

gamma = a gamma' / b .

Substituting into Eq. (2) and then dividing by Eq. (3):

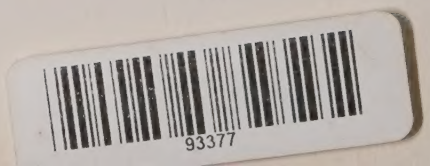
$$D_{Si_1} - D_{Fe_1} = \text{gamma} \log E_{rSi_1} / E_{rFe_1} = a/b \text{ gamma}' \log E_{rSi_1} / E_{rFe_1}$$

$$= a/b \, (D'_{Si_1} - D'_{Fe_1})$$

Thus, it is necessary only to multiply the density differences by a/ b to convert to values which may be used on the established working curves. This may be conveniently and quickly done on a slide rule.

C. H. and D. Curve and Scattered Light in the Densitometer

The H. and D. curve gives a very quick quantitative indication of the degree of light scattering present in the Densitometer. Without any light scattering, the H. and D. curve should be straight up to densities above 2.0. A good densitometer will surely maintain a straight H. and D. curve very close to a density of 1.7. Users of the Baird-Atomic instrument will discover that the straight line portion of the H. and D. curve extends very close to 2.0, and with careful adjustment probably to a higher density. However, if the distance of the pre-slit from the emulsion should become excessive, the instrument may exhibit more scattered light, and this will be immediately recognizable by an early curvature of the H. and D. curve as it approaches higher densities. Should the user discover that his H. and D. curves do turn off at a low density, the first thing to check is the positioning of the pre-slit. Frequent checks of this are not required, but certainly a check should be made at the time of installation. A symptom of this difficulty is obtaining density readings for lines of high density which are apparently much lower than they ought to be. It may be convenient in the laboratory to keep a standard reference plate on which spectra appear at high density which have been measured when the instrument has been adjusted for minimum light scattering. For example, such a plate taken at the time of installation has a line marked that has a density of 1.98. Occasional readings of this line as a check should give values in the vicinity of 1.98, unless the pre-slit requires adjustment.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